Standardized Requirements for Marking Electronic Components for Use with Automated Vision Systems

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ABSTRACT: This document provides requirements for marking unique identifiers (legends) onto electronic components for use with automated vision systems. This document specifies requirements for marking legends onto plastic, ceramic, and metal components.

APPLICABILITY: This document is written for external and internal electronic component suppliers, for personnel in Stage 1 modules manufacturing, and for external suppliers of automated vision systems.

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1 INTRODUCTION

The use of automated vision systems in the electronics industry for visual inspection is a reality; at Digital, the use of these automated vision systems is becoming more widespread. Inspection features include presence detection, orientation checking, and printed legend verification. Unfortunately, due to the vast number of electronic component manufacturers, legends are not standardized and are sometimes illegible even to human inspectors. Legends on electronic components can be decoded with automated vision techniques only if the legend character set agrees with the programmed character set. This creates the need for standardized legends that have the highest reliability for automated visual recognition under various lighting conditions.

Automated vision inspection can help reduce assembly defects and improve product quality. But to realize any advantages to using real-time automated vision systems for orientation and nomenclature verification, or supplier lot information on electronic components, standard character marking is necessary.

1.1 PURPOSE

This document provides standard requirements for marking electronic components so that automated vision systems can read part identifiers on assembled modules. These requirements pertain to substrate contrast, character sets, and legend orientation relative to a pin 1 designator bar.

Standardization shall ensure that automated vision systems detect the pin 1 designator.

1.2 SCOPE

This document covers most plastic, ceramic, and metal electronic component packages.

Electronic components covered, but not limited to, include:

- Dual Inline Packages (DIPs)
- Small Outline Transistors (SOTs)
- Small Outline Integrated Circuits (SOICs)
- Pin Grid Arrays (PGAs)
- All surface mount leaded components, including 25 and 50 mil pitch components, with or without heat sinks
- Surface Mount Technology Pin Grid Arrays (SMTPGAs)
- Surface mount transformers
- Surface mount oscillators
- Surface mount transistors
- Axial quad flat packs
- Opto-isolators
- Flat passive surface mount components

Many factors influence character recognition, including:

- Complexity of the field of view where the legend resides
- Illumination and optics
- The detection process itself, as accomplished with an electronic camera coupled to a vision computer
- Pattern recognition algorithms

Any attempt to analyze these factors in detail is beyond the scope of this document. This document specifies only those guidelines required to facilitate practical applications.

This document addresses automated vision verification and correlation of component legend nomenclature with known nomenclature data bases, prior to or after module assembly.

Detailed print quality inspection is beyond the scope of this document. See *American National Standard Character Set for Information Systems - Optical Character Recognition (OCR) - Guidelines for OCR Print Quality*.

This document does not specify or list all of the legend requirements for an electronic component. Legend requirements such as part number, component description, supplier logos, and lettering spacing, heights, and size must be specified in addition to the requirements defined in this document.

The requirements specified in this document do not apply to:

- Any electronic component where the legend appears on a nonflat surface.
- Any electronic component where the legend cannot be made visible to the automated vision system.

2 DEFINITION OF TERMS

bleed

A *bleed* is a portion of the character that should be empty, but is filled with ink (for example, the center of "0"). Bleeds can be used to measure how well a marking process retains the print within the intended character boundary.

character integrity

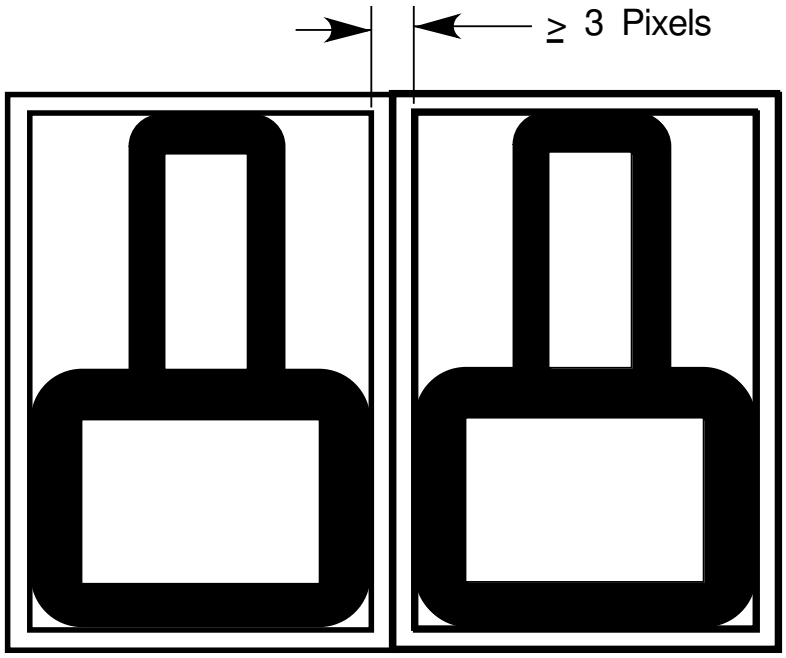
To be inspected accurately and consistently, characters must be well defined, that is, they must have *integrity*. They must not touch each other, and there can be no type *kerning*. Kerning refers to two characters that overlap, one beneath or above the other, in the same rectangular space. Touching or overlapping characters will cause a legend to be rejected.

Figure 1 shows proper separation between characters.

character set

A *character set* is a complete typeface font, including ASCII and other special characters, having unique dimensions and style.

Figure 1: Proper Separation Between Characters



Charmille

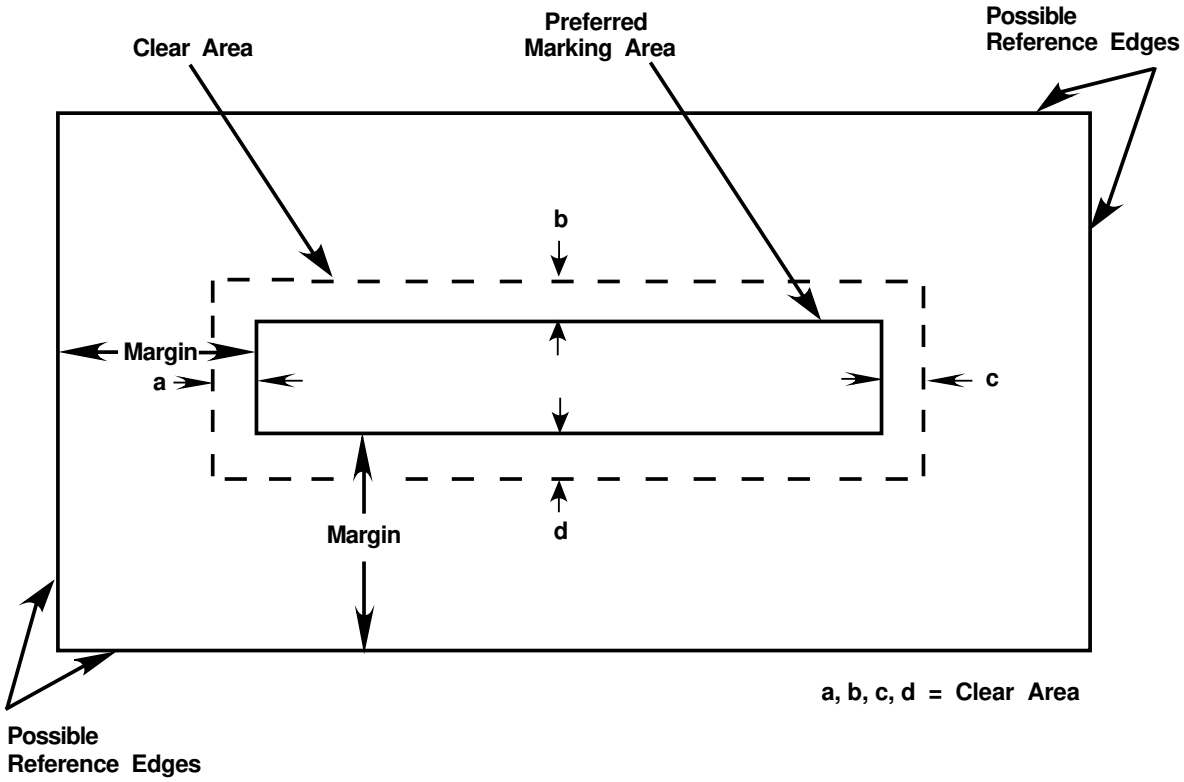
Charmille is an industry standard method for defining surface roughness of an injection-molded, epoxy-encapsulated integrated circuit. This method is intended to control the degree of *matte* finish to which the print adheres and is a guide to the finisher of the mold. The method involves a molded block, which can be obtained from the French firm, Charmille. This block has a number of degrees of roughness from polished to rough. Integrated circuit surface finishes can be specified between 1 and 24 Charmille. A Charmille rating of 1 defines the smoothest surface. A Charmille rating of 24 defines the roughest surface.

clear area

A *clear area* is an area extended by dimensions *a, b, c,* and *d*, as shown in Figure 2. This area is the clear zone between or without the mold marks on the legend surface. The locations and dimensions of clear areas, and any margins to adjust for mechanical alignment tolerances, shall be determined by individual applications.

The designator bar is on a legend surface that is designated as the surface with an easily visible plane that is parallel to the intended mounting surface.

Figure 2: Clear Area



contrast

Contrast is the range of difference between light and dark values in an image. Contrast is usually expressed as a *contrast ratio*, defined next.

contrast ratio

This refers to contrast ratio between brightness values, expressed in *gray levels*. *Contrast ratio* equals the difference between high gray level and low gray level readings, divided by the sum of high and low gray level readings, as measured by an automated vision system. See also *gray level* and *contrast*.

extended character set and logo

This term refers to any other character (for example, logo, electronic design symbol, and so on) that extends beyond the legend. See also *legend*.

feature

A *feature* is any significant geometrical shape or character dimension within a legend.

field of view

The *field of view* is the area of space imaged within the focal plane of a camera.

gray level

The *gray level* is a quantized measurement of image brightness, usually over 256 values, at eight bits per pixel.

kerning

Kerning is any part of the character that projects beyond its side bearings, where two characters overlap, one beneath or above the other, in the same rectangular space (for example, characters such as "AV" or "To"). See Figure 1.

lambertian surface

A *Lambertian surface* is a diffusing surface. The intensity of reflected light that emanates in any given direction from the surface is proportional to the cosine of the angle. Thus, the brightness of a lambertian surface is constant regardless of the viewing angle.

legend

A *legend* refers to all marked information to be verified or read by the vision system, including but not restricted to the pin 1 designator, part number, and date code.

matte

See definition for *lambertian surface*.

mottling or orange peeling

These terms refer to the resultant uneven nature of the surface of the print that forms the characters in a legend. This results from the marking process employed, ink formulation, substrate wetability, and the ink viscosity.

opacity

Opacity is the degree of print "show through" by the underlying substrate. It is principally impacted by the pigment loading and the print film thickness. This can be measured by the "reflectance" of the surface, as measured by a reflectometer. This is a subjective print quality parameter and becomes more important as the size of the character increases or as print produced by different processes are compared.

pixel

The term *pixel* is an acronym for the smallest "picture element" in a digitized image array.

void

A *void* is a missing portion of a character that exists entirely within a normally opaque region of the character and substantially impacts its readability. Examples include:

- A piece or character edge that changes the character outline
- A missing piece that is entirely included within the character

3 PIXEL SIZE

A pixel is the smallest "picture element" that an automated vision system camera can process. This means the system cannot "see" any feature smaller than one pixel. To ensure system repeatability, automated vision algorithms typically require 3 by 3 pixel features, otherwise noise elements (light, video, and so on) may produce inconsistent results.

The formula for determining the ratio of pixel size to the size of the area to be inspected is:

$$\text{Pixel size} = \frac{\text{field of view width}}{x}$$

where *field of view width* is the width of the smallest camera field of view that includes all of the features to be inspected and x is the number of pixels in one scan line of the camera. See also subhead 4.3.3.

To determine the smallest required field of view, measure the width of the smallest window that includes all of the features to be inspected. Divide the window size by x to arrive at the average pixel size.

Any feature that is to be repeatedly and accurately inspected must be at least 3 by 3 pixels in size. Most importantly, character stroke (line) thickness must be at least 3 pixels. See Figure 3.

For example, if all of the features to be inspected are contained in an area that is 0.6 inch wide, each pixel identified by a 512 by 512-pixel electronic camera will be about 0.0012 inch (0.6 inch/512 = 0.0012 inch). Any legend feature must be at least 3 pixels by 3 pixels, or 0.004 inch by 0.004 inch thick for proper verification or reading.

If any feature is less than three pixels, it may be possible to further reduce the field of view without eliminating any of the features to be inspected. In any case, lines or features that measure less than 3 by 3 pixels cannot be repeatedly and accurately detected.

4 PREFERRED CHARACTER SET

4.1 ANSI STANDARD OCR-A

The ANSI standard OCR-A is the character set required by this document. See *American National Standard Character Set for Optical Character Recognition (OCR-A)*.

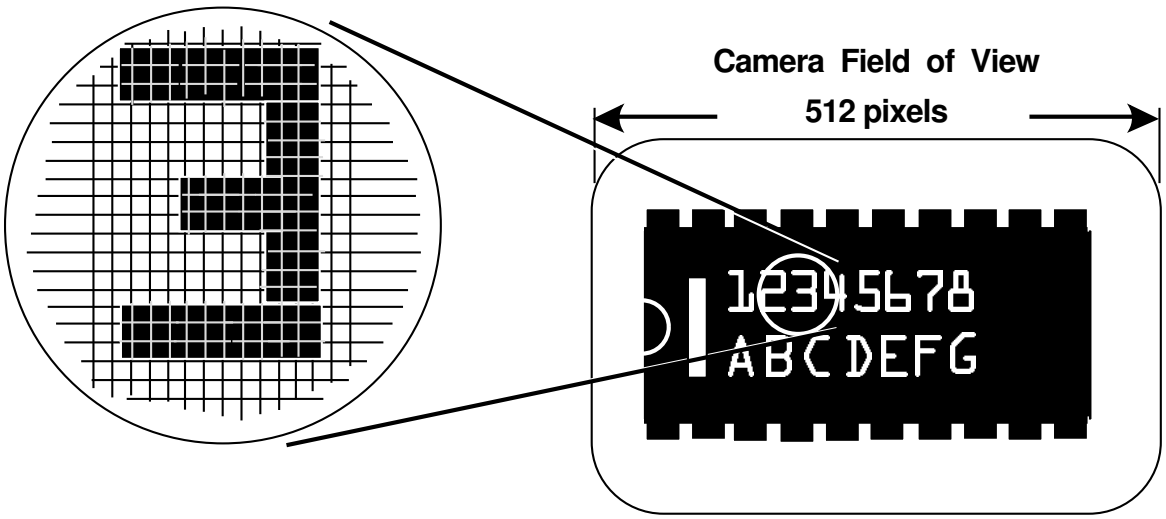
Only one character set per component shall be used for the legend nomenclature.

Figure 4 shows the OCR-A character set.

4.2 INCLUDED CHARACTERS

The character set includes capitals, numbers, and ASCII special characters. Fractions are not allowed.

Figure 3: Line Thickness



4.3 CHARACTER SIZE

4.3.1 Consistency

The ANSI standard OCR-A character set defines all other character set dimensions. See *American National Standard Character Set for Optical Character Recognition (OCR-A)*.

4.3.2 Height

The minimum character height of 0.031 inch shall be used.

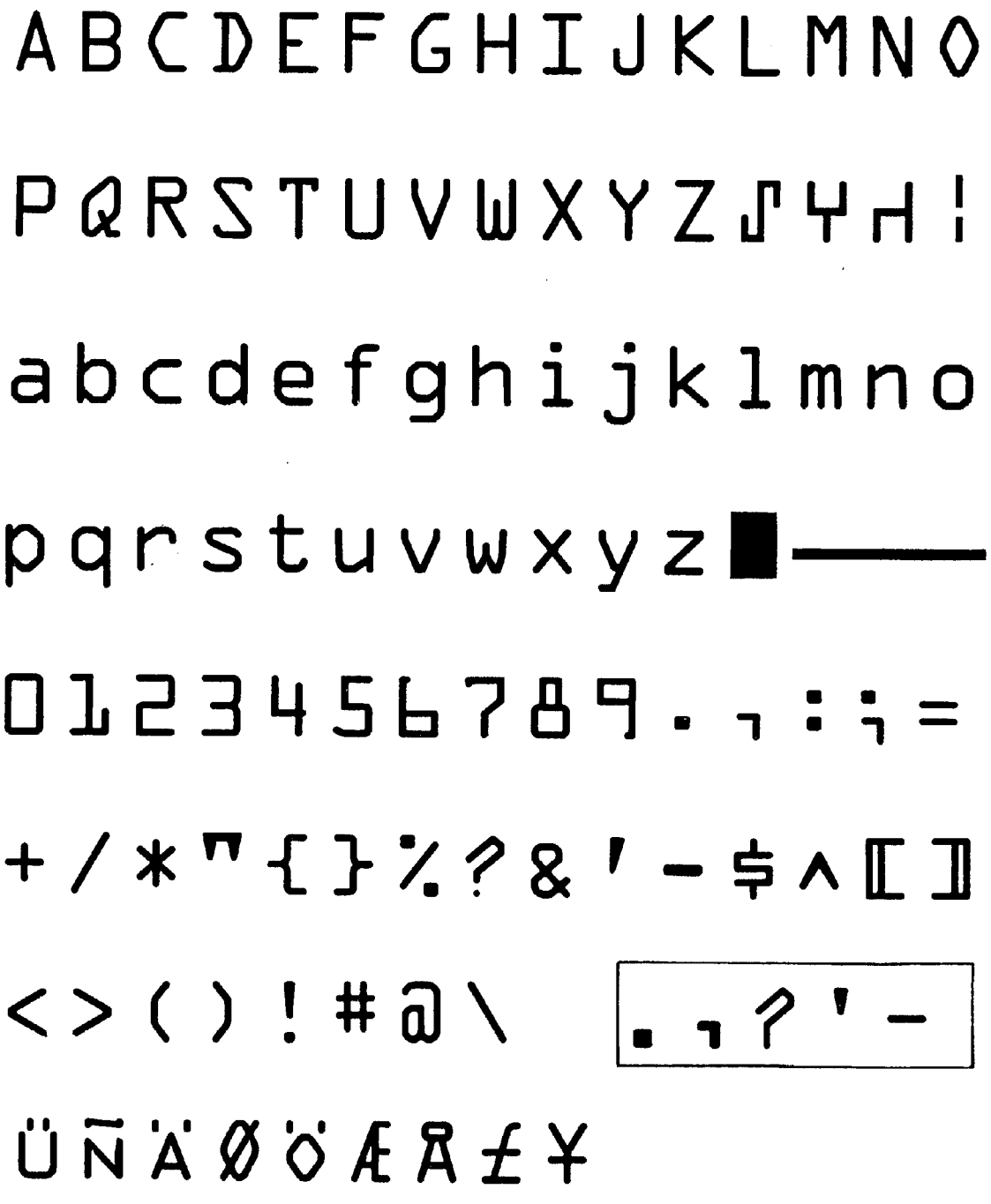
4.3.3 Minimum Feature Size Alternative

For extremely difficult-to-mark parts, a character may be of any size as long as it allows for repeatable verification or reading.

Most automated vision systems work well with minimum feature sizes that exceed 3 by 3 pixels. Therefore, character size shall be defined as:

$$\text{Minimum Feature Size} > \frac{3 \text{ times the field of view width}}{\text{number of pixels along the axis of measurement}}$$

Figure 4: OCR-A Character Set



5 SUBSTRATE FINISH

5.1 MATERIAL

Any standard packaging substrate (for example, plastic, metal, or ceramic) is acceptable.

5.2 ROUGHNESS

To make the automated vision reading and verification process as independent as possible from any variation in lighting conditions, the legend nomenclature characters shall be printed on a matte (lambertian) surface.

5.2.1 Plastic

The plastic surface onto which the legend nomenclature will be placed shall have a preferred charmille rating between 16 and 19.

5.2.2 Metal and Ceramic

All metal and ceramic surfaces used for marking legends shall have matte (lambertian) surface finishes.

6 LEGEND LOCATION AND LAYOUT

6.1 LEGEND SURFACE

The surface on which the legend is marked is designated as that plane parallel to any intended mounting plane.

6.2 LEGEND AREA

The legend area is that clear area (shown in Figure 2) between or without the mold marks on the legend surface. Figures 5a, 5b, and 5c show three different examples of available legend areas.

Legends to be inspected shall be contiguous within the defined field of view. Legends shall not overlap component edges or any other non-coplanar surface (for example, injection molding marks, caps, chamfers, and so on). The legend shall be removed at least the minimum feature size (defined under subhead 4.3.3) from the pin 1 designator bar (defined under subhead 6.7) from any component edge or any other non-coplanar surface.

Figure 5: Legend Area

Figure 5a. Legend Area—First View

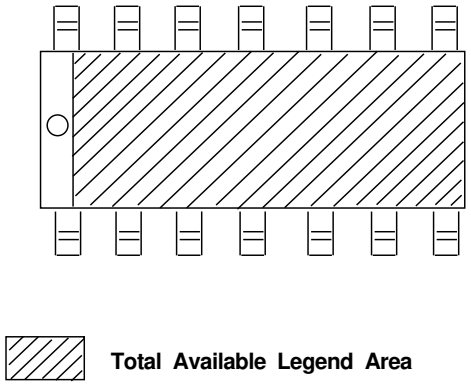


Figure 5b. Legend Area—Second View

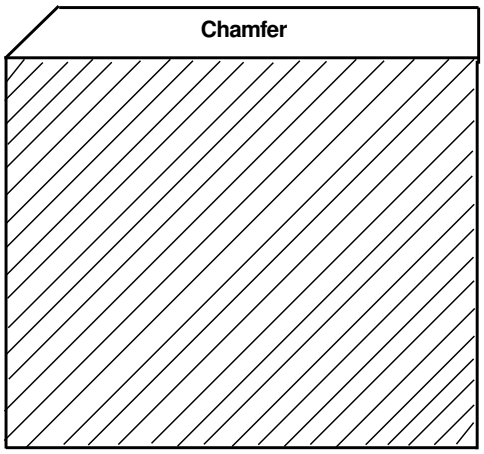
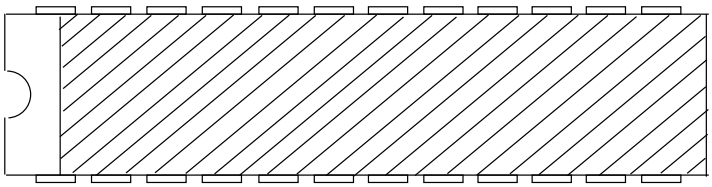


Figure 5c. Legend Area—Third View



6.3 LEGEND COLOR

Legend color on plastics and ceramic electronic components is preferably white-on-black or black-on-white. On metal surfaced electronic components where the surface may be silver or gold, a black legend is necessary for automated vision systems to read and verify the characters reliably.

6.4 CHARACTER SPACING

Each character must occupy its own space.

The minimum spacing between characters shall be 0.004 inch. Alternatively, the minimum spacing between characters shall be three pixels.

6.5 KERNING

Kerning shall not be permitted. Each character shall occupy its own rectangular space. See Figure 1.

6.6 LINE SPACING

Each line must occupy its own space.

The minimum spacing between lines shall be 0.004 inch. Alternatively, the minimum spacing between lines shall be three pixels.

6.7 PIN ONE DESIGNATOR BAR

Whenever any marked pin 1 designation is used, it shall be indicated by a bar or stripe that is:

- Of the same marking and labeling print as the alphanumeric characters in the component's legend
- No less than 0.025 inch wide
- Separated from the legend by at least 0.004 inch
- Perpendicular to the legend nomenclature, whose length is at least as long as the alphanumeric legend is high
- The closest print marking within the legend area to pin 1
- On the same side of the component as the legend, but preceding the legend

The alphanumeric characters in a legend must appear right side up with the pin 1 designator bar to their left. (See Figure 6 under subhead 8.2.) This bar shall not be rotated relative to the legend nomenclature more than ± 3 degrees.

6.8 LEGEND ROTATION

A maximum rotation of ± 3 degrees, with respect to the component edges, is allowed.

6.9 COMPANY LOGOS

Any company logo shall not overlap or obscure any print within the legend area.

7 PRINT QUALITY PARAMETERS

When an automated vision system, while reading or verifying legend nomenclature, detects a legend that fails to meet one or more print quality parameters, the system shall reject the component as improperly marked.

7.1 CONTRAST

7.1.1 Gray Scale Contrast Ratio

To be correctly inspected, legend characters must have sufficient contrast between the color of the legend and the color of the component. The difference in contrast levels between a "good" legend and a "bad" legend must be clearly visible to the human eye. Like all measurement systems, an automated vision system has finite accuracy. If the difference between an acceptable and unacceptable legend is not clearly visible to the human eye, the vision system will not be able to detect it either. If this is a problem, improving the marking process to produce a higher contrast legend is a possible solution.

For the purposes of this document, *gray scale contrast ratio*, G, is a ratio between brightness values, expressed in gray levels as measured by an automated vision system. The contrast ratio equals the difference between high gray level and low gray level readings, divided by the sum of high and low gray level readings.

The minimum acceptable *contrast ratio*, C, between the print opacity and component substrate is 0.3, or:

$$C = \frac{G_1 - G_2}{G_1 + G_2} > 0.3$$

where:

G_1 = The average gray level of the black bars or background measured using any automated vision system.

G_2 = The average gray level of the white bars or background measured using any automated vision system.

All legend characters and the pin 1 designator bar shall also meet the minimum acceptable contrast ratio.

The standard industry definition of contrast ratio is the ratio of a black/white planar lambertian bar pattern with spatial frequency of approximately three lines per millimeter detected through a system that is able to resolve twice that spatial frequency (six lines per millimeter).

7.1.2 Print Uniformity

Legend quality is related to the relative contrast achievable between the substrate and legend. Component surfaces vary in color quality and finish, ranging from anodized aluminum, black plastic, and gray and white ceramic, to white plastic. Marking methods vary from black ink, laser scribe, and gray or white ink, to white or black stenciled ink. Some surface/ink combinations also include metallic surface with metal absence marking. The primary consideration on surface/ink combination is relative pixel contrast.

A second element of print quality relating to contrast is the stability of the contrast legend. The variations in the legends fall into two categories:

- Variations in print coverage
- Variations in print reflectance

Both of these affect the automated vision system's ability to decode legends. Variations in coverage are related to the method of marking. Laser scribing has the least variation in area, while stenciled marking has the most variation.

Reflectance variations, on the other hand, vary with print thickness and surface finish quality. Typically, legend opacities vary by about 10 percent. However, the surface finish quality of the component substrate can vary over larger ranges, due to changes in the surface finish during manufacturing. Limited measurements on plastic integrated circuits have shown print reflectance fluctuations of 5 to 10 percent and substrate surface reflectance fluctuations of 25 percent.

7.1.3 Print Opacity

The print opacity shall exceed that required to satisfy the contrast ratio standard given under subhead 7.1.1 for any portion of a character.

The contrast ratio can vary with changes in the print opacity, which allows a portion of the substrate surface to show through. This could result in situations where legend information is unrecognizable.

7.2 MISSING CHARACTERS

The legend information is incomplete if one or more characters is missing in the legend according to the specified location for the component's legend information.

7.3 CHARACTER SHAPE

For the purposes of this document, a character is defective if it does not have a shape that is consistent with the ANSI standard OCR-A character set for that character.

7.4 CHARACTER-TO-CHARACTER ORIENTATION

Character-to-character position or rotation shall not vary relative to the definition of an overall line of characters in the legend by more than $\pm$ 3 degrees.

8 REQUIREMENTS SUMMARY

The following table shows examples of minimum requirements, in pixels and inches, for some parameters.

Parameter	Pixels	Inches
Field of View Width	512	0.6
Pixel Height and Width	1	0.0012
Minimum Line Thickness	3	0.004
Minimum Spacing	3	0.004
Minimum OCR-A Character Height	25	0.031
Minimum OCR-A Character Width	17	0.021
Minimum Horizontal Pitch	20	0.025
Minimum Vertical Pitch	28	0.035

8.1 MINIMUM IMAGE SIZE

Given a 512 by 512 pixel electronic camera with a maximum field of view of 0.6 inch by 0.6 inch, a single pixel is about 0.0012 inch by 0.0012 inch.

8.2 MAXIMUM NUMBER OF CHARACTERS

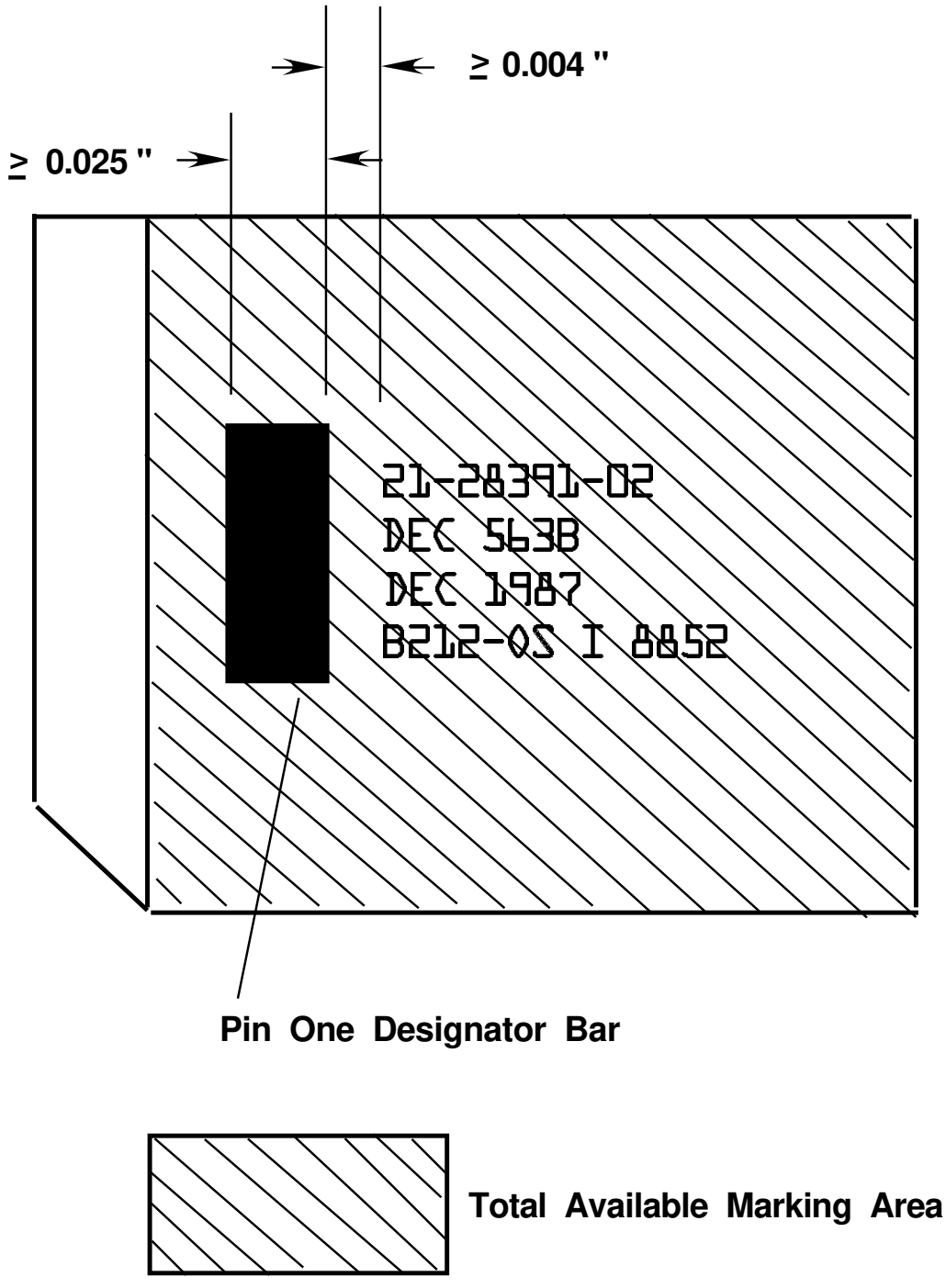
Given a 512 by 512 pixel electronic camera with a maximum field of view of 0.6 inch by 0.6 inch, the total number of characters per legend line is consistent with the ANSI standard OCR-A character set widths and character spacings that can fit within a 0.6-inch by 0.6-inch field of view, which includes the pin 1 designator bar.

Figure 6 shows an example of an electronic component marked according to the requirements specified in this document.

8.3 MAXIMUM NUMBER OF LINES

Given a 512 by 512 pixel electronic camera with a maximum field of view of 0.6 inch by 0.6 inch, the number of lines of legend nomenclature is dependent on the standard sizes defined for the characters by the ANSI standard OCR-A character set. The lines must fit within a 0.6-inch by 0.6-inch field of view.

Figure 6: Example of an Electronic Component Legend



9 LEGEND LEGIBILITY

A legible marking is one that can be read or recognized by human inspectors or by automated vision equipment.

Figure 7 shows various defects that would be detected by an automated vision system.

Figure 7: Marking Defects

Figure 7 available only in hardcopy.

APPENDIX A HISTORY OF THE OCR-A CHARACTER SET

The American National Standards Institute (ANSI) standard OCR-A character set was developed by ANSI for Optical Character Recognition (OCR) with the cooperation of the International Standards Organization (ISO). In July, 1966, the character set was approved as the USA Standard Character Set for Optical Character Recognition (X3.17, 1966). In 1966, the character set became part of an ISO recommendation (Number 996) which was circulated for voting to national standards organizations in June, 1967. In the ISO recommendation, the character set is referred to as OCR-A, and this identification is now used throughout the industry.

The ANSI/ISO goal was to develop a character set suitable for both human and automated reading without restricting the future development of automated recognition techniques. Further considerations were that the character shapes in the recommended sizes should be accurately printable on existing and proposed printing machines using supplies of a quality readily available in the marketplace, and that the number of characters in the character set should be sufficient to satisfy the requirements of the maximum number of applications.

To ensure that these goals were met, the development of OCR-A was organized into three groups:

a. *Character Development:* This group was responsible for the design of the character shapes, including definition of the criteria to be used in shape selection.

b. *Print Machines and Printing:* This group initially concentrated upon the identification of the printing machines expected to be used in OCR applications and on measurement of the variation in print quality representative of these machines. It was soon recognized that the choice of supplies (paper, ink, ribbon, and so on) can have a marked effect on print quality and, conversely, that the definition of print quality can affect both the price and availability of supplies. Therefore, the printing activity was expanded to include the development of specifications for supplies.

c. *Applications and Format:* This group considered OCR applications corresponding to the numbers of characters to be developed in the character set. Several applications were identified as being satisfied by a numeric symbol set; others required a full alphanumeric set. This information was developed from an analysis of applications for which OCR was being used or considered.

A great deal of effort was spent in the development of evaluation criteria that would provide a quantitative measure in distinguishing a set of character shapes. It was recognized that many different recognition techniques were available or under development in laboratories and that, for proprietary reasons, full information could not be made available on much of this work. Because of the wide disparity between the many efforts directed toward an "Optical Character Recognition" system, it was felt that no method for distinguishing would be adequate and, further, that a single evaluation technique, if chosen, would restrict future development of OCR technology.

Altogether, 14 technical and subjective criteria were identified. They included the following.

- Characters must be reasonably pleasing in appearance and should be accurately and easily readable by human beings.
- All strokes must have uniform width.
- Characters shall be constructed with a minimum of serifs.
- All radii and fillets should be noncritical; that is, they should have no effect on automated readability.
- Characters should be designed for maximum distinction based on two-dimensional information. They need not be recognizable solely on the basis of information contained in vertical or in horizontal strokes.

However, these five criteria are sufficient for automated reading and machine printing.

To ensure that full use was made of all information available during the development of OCR-A, every company known to be attempting to develop or market a reading system was invited to participate.

APPENDIX B REFERENCE DOCUMENTS

- *JEDEC Registered and Standard Outlines for Semiconductor Devices*, Electronic Industries Association, Washington, D.C. JEDEC Publication 95
- *American National Standard Character Set for Optical Character recognition (OCR-A)*, American National Standards Institute, New York, N.Y., ANSI Standard X3.17-1981
- *American National Standard Character Set for Information Systems - Optical Character Recognition (OCR) - Guidelines for OCR Print Quality*, American National Standards Institute, New York, N.Y., ANSI Standard X3.99-1983